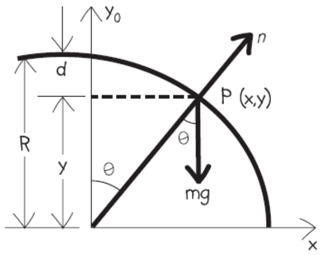
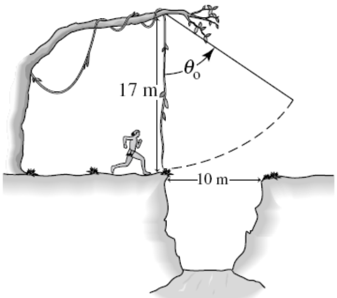
Chapter 7

54. If all the water fell through the same difference in height, the amount of gravitational potential energy released would be $\Delta U = mg\Delta y = (8.5\times 10^9\ \text{kg})(9.8\ \text{m/s}^2)(140\,\text{m}) = 1.17\times 10^{13}\,\text{J}$. The energy generated by the power plant at an average power output of 330 MW over an 8 h period is $(330\ \text{MW})(8\times 3600\ \text{s}) = 9.50\times 10^{12}\,\text{J}$, so the fraction lost is $(11.7-9.50)/11.7 = 18.5\%$.

62. The conservation of mechanical energy between points O and P requires $K_0 + U_0 = K + U$, or $mgR = \frac{1}{2}mv^2 + mgy$ (since the bug starts from rest). Thus, $v^2 = 2g(R-y) = 2gd$. The bug leaves the surface when the normal force has decreased to zero. From the radial component of Newton's second law, $mg\cos\theta - n = mv^2/R$, so this occurs when $n = mg\cos\theta - mv^2/R = 0$, or $v^2 = gR\cos\theta = gy = g(R-d)$. Combining these results, we find $v^2 = 2gd = g(R-d)$, or $d = \frac{1}{3}R$.



64. If we treat Tarzan as a simple pendulum, then we know that his kinetic energy $\frac{1}{2}mv^2$ at the bottom of his swing equals his potential energy $mgL(1-\cos\theta_0)$ at the top. The value of the maximum angle θ_0, which puts Tarzan vertically over the opposite rim of the gorge, is found from the condition $L\sin\theta_0 = 10$ m, or $\theta_0 = \sin^{-1}(10/17) = 36.0°$. Then $\frac{1}{2}mv^2 = mgL(1-\cos\theta_0)$ implies $v = \sqrt{2(9.8\ \text{m/s}^2)(17\ \text{m})(1-\cos 36.0°)} = 7.98$ m/s.



65. **Interpret** We find whether a spring-launched block makes it to the top of an incline with friction, and how much kinetic energy it has when it gets there (if it gets there.) We can use energy methods to solve this problem, but friction is a factor so mechanical energy is not conserved.

Develop The initial energy of the system is spring potential energy. The final energy is gravitational potential, kinetic, and we also count the mechanical energy lost to friction. $U_i = U_f + K_f + W_f$. The weight of the block is $mg = 4.5$ N. The angle of the incline is $\theta = 30°$, and its length is $L = 2.0$ m. The spring constant is $k = 2.0$ kN/m, and the initial spring compression is $x = 0.1$ m. The coefficient of kinetic friction is $\mu = 0.5$. We solve this for K: if K is positive for $s = L$, that is the amount of kinetic energy remaining at the top. If it's negative, we'll go on to find the value of s that makes K zero. Finally, we need to repeat our answer for a block of twice the weight.

Evaluate

(a) We will define the distance the block travels up the incline as s. The height change for this distance is then $h = s\sin\theta$.

$U_i = U_f + K_f + W_f \to \frac{1}{2}kx^2 = mgh + \frac{1}{2}mv^2 + F_f s = mgs\sin\theta + \frac{1}{2}mv^2 + \mu mgs\cos\theta$. Solve for K:

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 - mgs(\sin\theta + \mu\cos\theta) = 1.60$ J. The block reaches the top, with 1.6 J of extra kinetic energy.

(b) We use the same equation for K, but this time with $mg = 9$ N: $\frac{1}{2}mv^2 = \frac{1}{2}kx^2 - mgs(\sin\theta + \mu\cos\theta) = -6.79$ J. It does *not* reach the top. Now we solve for the distance s, with $v = 0$. $s = \frac{\frac{1}{2}kx^2}{mg(\sin\theta + \mu\cos\theta)} = 1.19$ m.

Assess The mass cannot have negative kinetic energy. We use this to our advantage in the problem.

Chapter 8

54. The same reasoning as applied in the previous problem, with the same approximations and the neglect of the Earth's rotation, gives $v^2 = v_0^2 + 2GM_E(r^{-1} - r_0^{-1})$. Here, v_0 is the launch speed of the rocket, $r_0 = R_E$ at the Earth's surface, and $r = 3.85 \times 10^5$ km crossing the Moon's orbit, so $v^2 = v_0^2 - 1.23 \times 10^8\,(\text{m/s})^2$. For the values of v_0 given, 12 and 18 km/s, $v = 4.59$ and 14.2 km/s, respectively.

60. In a lower circular orbit (smaller r) the orbital speed is faster (see Equation 8.3). The time for 10 complete orbits of the faster satellite must equal the time for $9\frac{1}{2}$ geosynchronous orbits, if the faster satellite is to catch up as described (it starts out one-half an orbit behind). Thus, $10T = 9.5(1\text{ d})$, or $T = 0.95$ d, where T is the period of the lower, faster orbit. Kepler's third law (Equation 8.3) then gives $r = (GM_E T^2/4\pi^2)^{1/3} = (0.95)^{2/3} r_{GS}$, since for the geosynchronous orbit, $(GM_E/4\pi^2)^{1/3} = r_{GS}/(1\text{ d})^{2/3}$, where $r_{GS} = 42{,}200$ km (see Example 8.3). The difference in the orbital radii is $r_{GS}, - r = [1 - (0.95)^{2/3}](42{,}200\text{ km}) = 1420$ km. (We neglected the time spent in changing orbits as suggested.)

62. **Interpret** The orbital period of the Moon is increasing at about 35 ms per century. We assume that the Moon's orbit is approximately circular, and find the rate of change in the Earth-Moon distance.

Develop We are given the hint that we should differentiate Kepler's third law: $T^2 = \frac{4\pi^2 r^3}{GM}$. We use the value of the gravitational constant $G = 6.673 \times 10^{-11}\ \frac{\text{N m}^2}{\text{kg}^2}$, the mass of the Earth $M = 5.97 \times 10^{24}$ kg, and the radius of the Moon's orbit $r = 3.84 \times 10^8$ m. The rate of change in T is $\frac{dT}{dt} = \frac{35\text{ ms}}{100\text{ years}} = \frac{35 \times 10^{-3}\text{ s}}{\pi \times 10^9\text{ s}} = 1.11 \times 10^{-11}$.

Evaluate $T = \left(\frac{4\pi^2 r^3}{GM}\right)^{1/2} = \left(\frac{4\pi^2}{GM}\right)^{1/2} r^{3/2} \rightarrow \frac{dT}{dt} = \left(\frac{4\pi^2}{GM}\right)^{1/2} \frac{3}{2} r^{1/2} \frac{dr}{dt}$. Solve this for $\frac{dr}{dt}$ to obtain

$\frac{dr}{dt} = \frac{dT}{dt}\left(\frac{GM}{4\pi^2}\right)^{1/2} \frac{2}{3\sqrt{r}} = 1.2 \times 10^{-9}$ m/s $= 3.8$ m/century.

Assess We don't have to worry about the Moon leaving any time soon, at this speed!